3D printing of patient-specific 316L-stainless-steel medical implants using fused filament fabrication technology: two veterinary case studies

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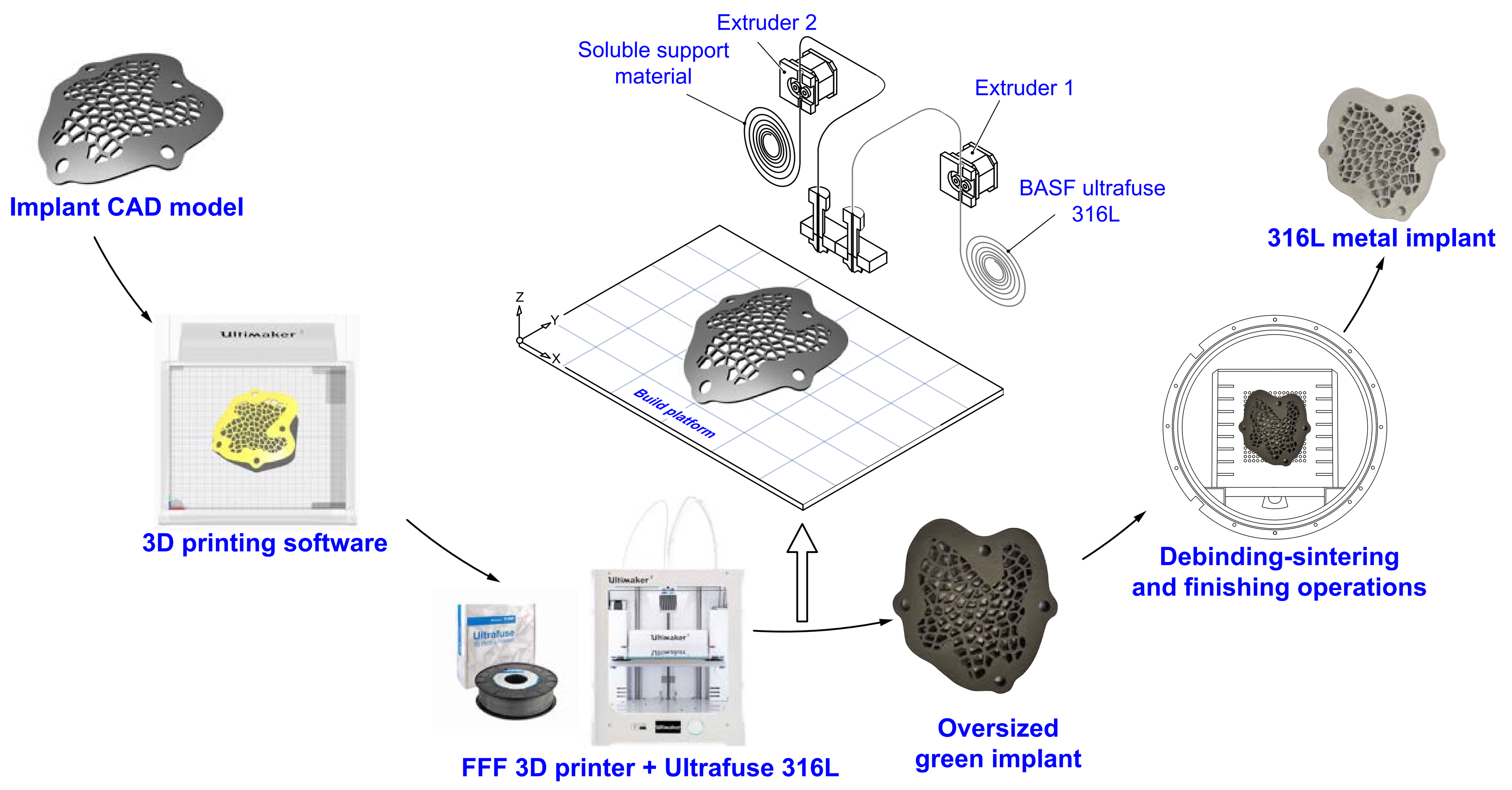
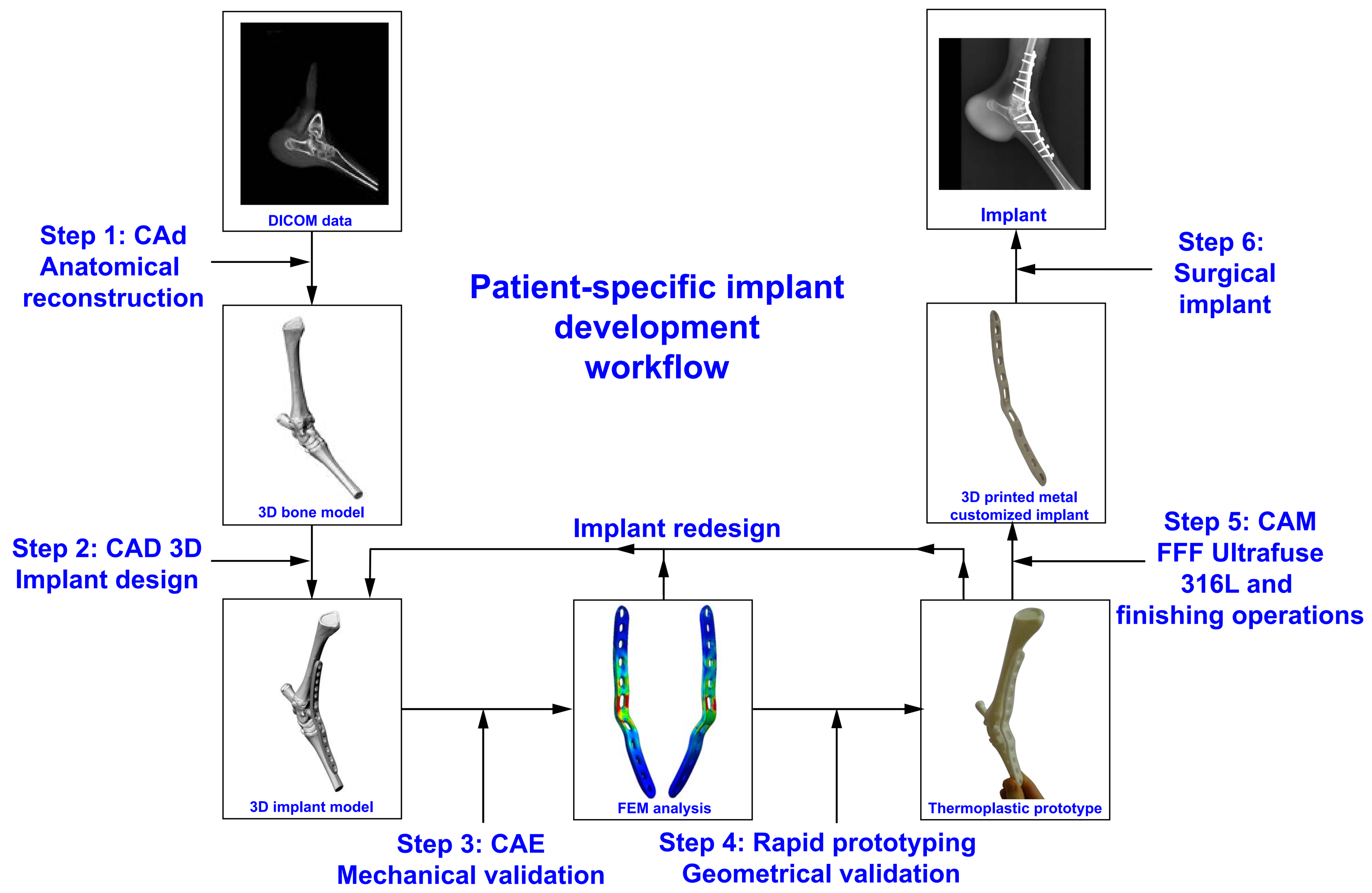
Biomedical fracture fixation implants have complex sculptured geometries to adapt perfectly to fractured bones, making them difficult and expensive to manufacture with conventional machining methods. Fused Filament Fabrication (FFF) is a very popular Additive Manufacturing technology that simplifies the manufacture of customized medical implants.The use of FFF-based new engineering biocompatible thermoplastic materials opens new possibilities for the manufacture of patient-specific biomedical implants. This study explored an innovative technology for designing and manufacturing patient specific biomedical implants using standard computer-aided technology (CAx), and FFF-based 316L stainless steel manufacturing with subsequent debinding and sintering stages. The goal was to establish a systematic workflow for the manufacturing of biomedical implants.

Proposed workflow via CAx and FFF for the design and manufacture of customized implants

- **Step 1:** Digital anatomical reconstruction of the fractured bone via a computer-aided diagnosis (CAd) system.
- **Step 2:** Development of a patient-specific bio-designed implant using computer-aided design (CAD 3D).
- **Step 3:** Mechanical validation using computer-aided engineering (CAE) via finite element method (FEM) analysis.
- **Step 4:** Geometrical validation via rapid prototyping using thermoplastic materials.
- **Step 5:** FFF of the metal implant using an AM computer-aided manufacturing (CAM) system and finishing operations.
- **Step 6:** Surgical patient-specific prosthesis implant.

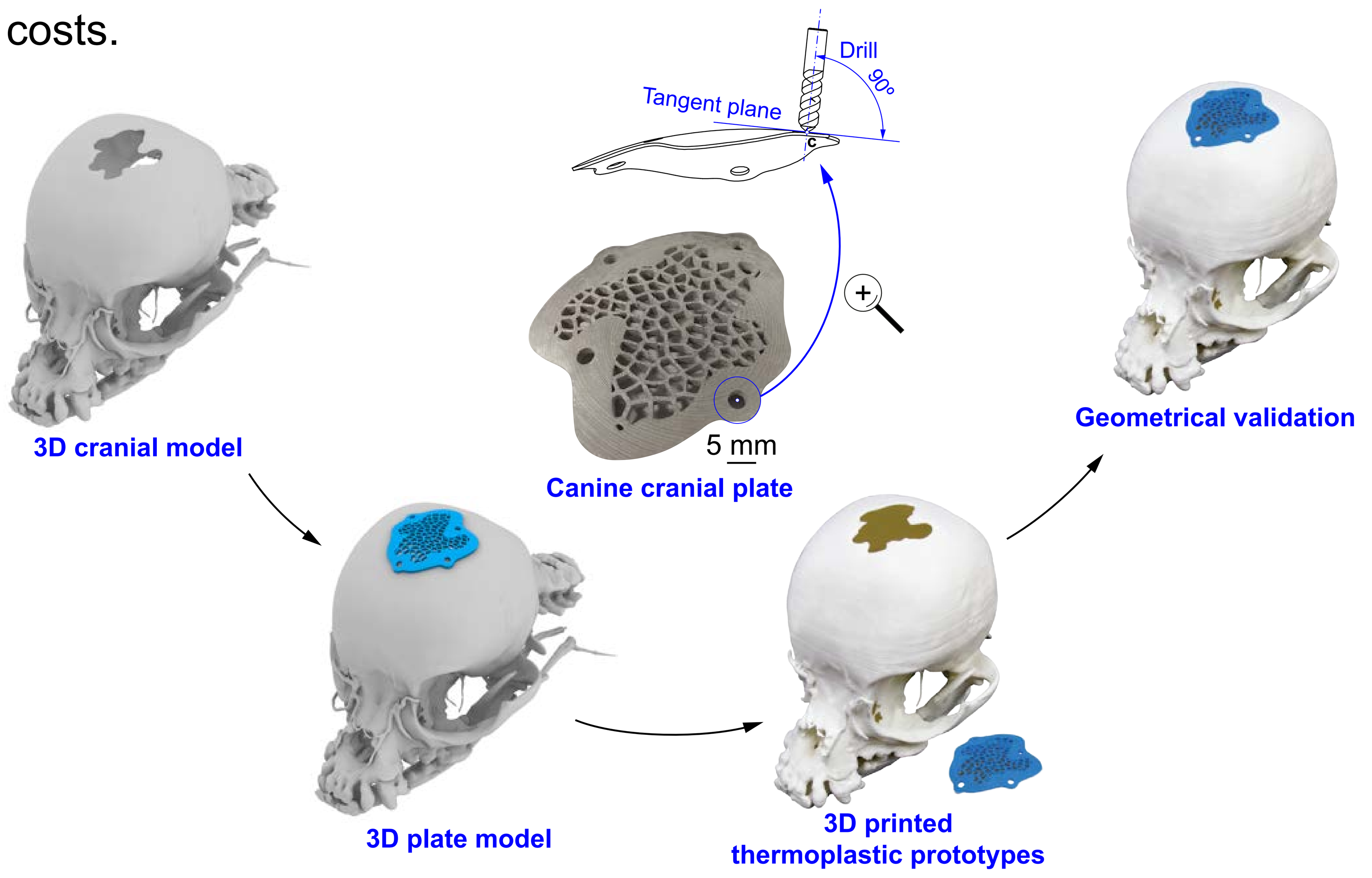




Two veterinary case studies

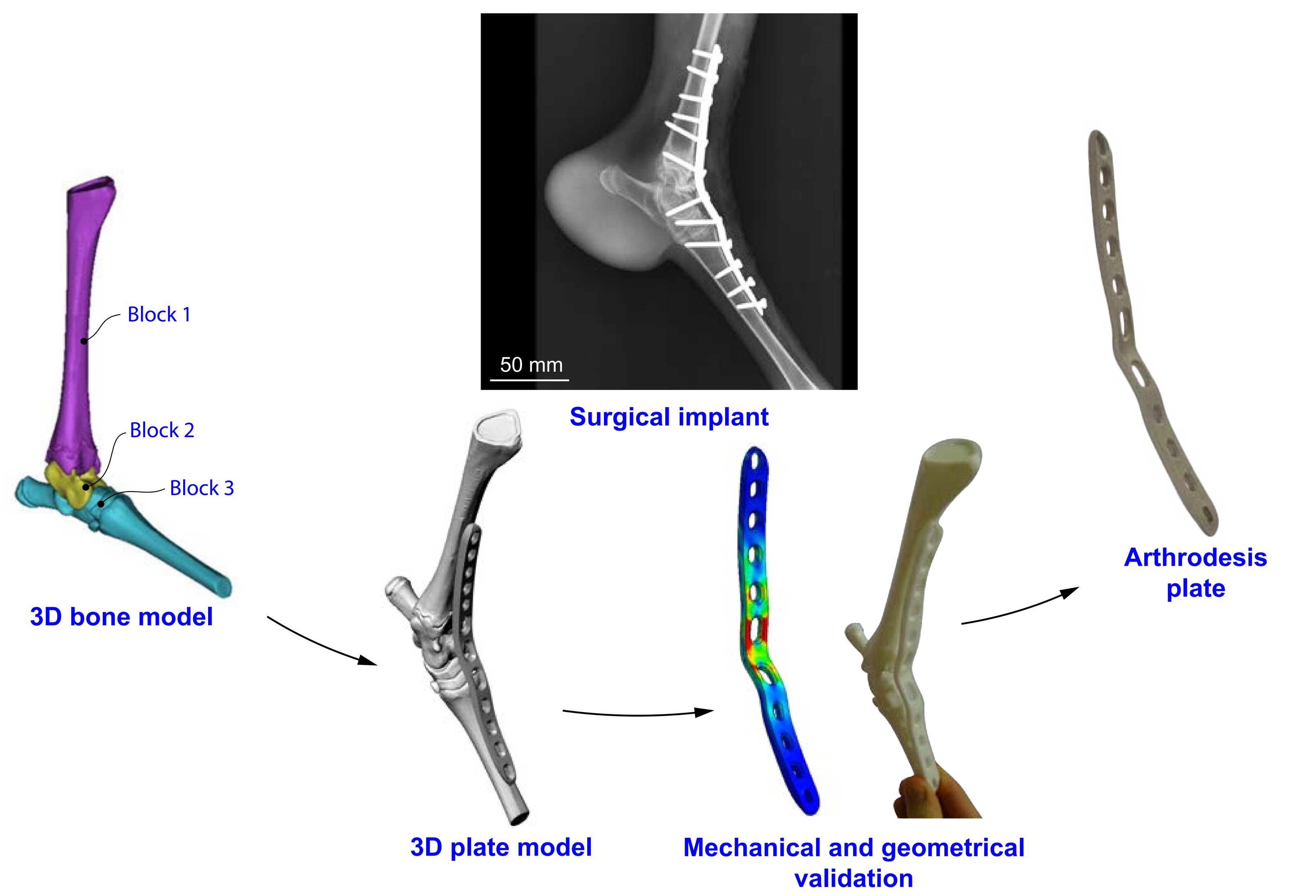
Canine cranial implant

The animal was diagnosed with a fractured and collapsed skull and severe brain trauma. As repositioning of the bone fragments into the correct place was not possible, the veterinary team decided to place a customized cranial plate adapted to the shape of the skull. A canine cranial implant was manufactured with the FFF technique in order to reduce fabrication costs.



Dorsal pantarsal arthrodesis plate

This case involved the fabrication of a dorsal pantarsal arthrodesis plate with the goal of repairing a rupture of the gastrocnemius tendon in a lamb. A standard-size implant could produce bone fractures in the affected limb, and the reshaping of a fixation plate could be inefficient and inaccurate. The veterinary team decided to use a customized implant adapted to the limb.



Conclusions

- Ultrafuse® 316L stainless steel/polymer composite filament was used for the manufacturing of customized metal implants with a low-cost 3D printer.
- The proposed CAx workflow reduces design time and in turn patient-specific development time and costs.
- This approach enables the reduction of the manufacturing costs and time of patient-specific implants.
- The precision of the entire AM process is superior in precision to anatomic reconstruction via CAd.

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